Limits to International Arbitrage: An Empirical Evaluation

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Abstract

This paper studies international financial integration by testing the law of one price across national borders. We extend the methodology as proposed by Chen and Knez (1995) to an international environment and analyze the level of cross-border mispricings. The empirical analysis shows that pricing errors are relatively large. This lack of international financial integration is subsequently analyzed in the market micro-finance literature. We find that micro-factors explain a considerable part of the variance in cross-border pricing errors.

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1 Introduction

In recent years, evidence of imperfect financial market integration is accumulating. Defining integration in terms of (cross-market) mispricing, many authors have documented large and persistent mispricing anomalies. At least two strands of literature can be distinguished. The first type studies whether prices reflect fundamental values and analyzes the role of national risk factors in the pricing of assets. If financial markets are perfectly integrated internationally, none of the purely national factors are priced. Empirical tests of this approach to testing international integration have documented the importance, both in statistical and economic terms, of national pricing factors (see for instance Jorion and Schwartz (1986)). This strand of literature is called absolute valuation as one needs some equilibrium model of asset pricing, e.g., CAPM or IAPT type of models, to determine the fundamental value of assets. The main drawback of this approach is that fundamental values are unobservable and hence that the test of market integration is always a joint test of the validity of the pricing model and market efficiency.

A second strand of literature uses no restriction on the pricing model, but tests the relative valuation of assets as defined by the law of one price. The advantage of this methodology is that one only needs to know whether identical assets have identical prices. The difficulty with this methodology is that one is restricted in the class of assets that can be valued relative to a base asset. A typical test examines closed-end funds (see Hardouvelis et al. (1994) and Bodurtha et al. (1995)), dual listed companies, so-called Siamese-twin stocks, (see Froot and Dabora (1999) and de Jong et al. (2003)), or equity carve-outs (see Lamont and Thaler (2003)). A robust finding of this literature is that mispricing levels over 15 percent are more the rule than the exception.

The main goal of this paper is to analyze international financial integration. While the above mentioned approaches can be used to measure international financial integration, we propose an alternative that overcomes the drawbacks of each of the approaches. First, to overcome the problem of jointly testing an absolute pricing model together with integration we focus on relative pricing tests. The main problem with the latter approach is the restricted set of assets that allow direct tests of relative pricing. We propose a method to extend this set significantly. By using techniques proposed by Chen and Knez (1995) one can in principle assess the relative pricing errors of any type of asset or portfolio. This extension of the set of relative pricing assessments is important because it allows us to generate sufficiently many data to study the determinants of relative pricing errors. That is, based on a large sample of relative pricing errors we focus on market micro-structure explanations of mispricing.

The paper proceeds in two steps. First, we examine the law of one price to assess the degree of financial integration. We apply a method proposed by Chen and Knez (1995), which builds on the Hansen-Jagannathan pricing framework (1997). Taking into account the international no-arbitrage condition, this methodology is extended to measure international financial integration. Since this is a general pricing framework, we can measure cross-market integration with a minimum of additional pricing assumption.[1] We are not restricted to certain types of assets, and mispricing errors are assessed without any reference to a functional asset pricing model. The measured degree of mispricing appears in terms of an upper bound on pricing errors. We do find this pricing bounds to be relatively high and economically important.

Subsequently, we proceed by analyzing factors that may explain the observed lack of international financial integration. We concentrate on the most important channels that have been suggested by the micro-finance theory. Arbitrage opportunities (mispricing) may exist because arbitrageurs may face impediments not incorporated into the standard pricing theories. We analyze some of the factors suggested in the theoretical literature such as market value, market volatility and market activity. We find that most of these micro factors explain (in cross-section) a significant part of the variance of the pricing errors across markets.

The remainder of the paper is organized as follows. In Section 2, we introduce the Chen and Knez (1995) methodology that measures the degree of mispricing across markets. Building on their methodology we extend this measurement theory to an international financial environment and concentrate on the cross-market mispricing measures. Subsequently, Section 3 presents the empirical analysis on international financial integration between US and European financial markets. These pair-wise measures of mispricing are then used as an input in the second part of Section 3 where we try to explain the degree of mispricing between two markets by means of the above listed micro-factors. Finally, Section 4 concludes.

2 Measuring financial integration

In this section we extend the integration metric introduced by Chen and Knez (1995) (CK) to an international setting. The CK-measure of market integration is appealing as it is not tied to any specific asset pricing model. The only underlying principle of the measure is the law of one price: identical assets, sold in any market, should sell at the same price. Deviation of two market prices then suggests deviations of the law of one price and the existence of cross-market arbitrage opportunities. We use this integration metric to measure international

[1] More specifically the only assumption to be made is the assumption of mean square integrable pricing processes.

financial integration by studying the law of one price in an international context.

2.1 The law of one price and arbitrage opportunities

Consider a set of asset prices on a specific financial market $P_{i,t}$, for $i = 1, ..., N$ with (stochastic) future payoffs $X_{i,t+1}$. If the law of one price is satisfied within that market, there exists a pricing kernel m such that:

$$P_{i,t} = E_t \left[m_{t+1} X_{i,t+1} \right]. \tag{1}$$

Analogously, we introduce a second financial market with different numeraire (different currency) by positing a pricing kernel m^* and a set of prices $P^*_{i,t}$ with stochastic payoffs $X^*_{i,t+1}$, $i = 1, ..., N^*$. Again assuming that the law of one price holds, implies the existence of the pricing kernel m^* such that:

$$P^*_{i,t} = E_t \left[m^*_{t+1} X^*_{i,\ t+1} \right]. \tag{2}$$

Equations (1) and (2) ensure that the law of one price holds in each financial market separately. Extending the law of one price across markets requires an additional restriction on the exchange rate dynamics. A sufficient condition to ensure international no-arbitrage is the so-called complete market assumption formulation of the exchange rate dynamics (see Brandt et al. (2001) and Backus et al. (2001)):

$$m^*_{i,\ t+1} = m_{i,t+1} \frac{S_{t+1}}{S_t}, \tag{3}$$

where S_t denotes the unit price of foreign currency in terms of domestic currency. This condition is sufficient to extend the law of one price to international investment opportunities. The three pricing equations, (1) to (3), impose no-arbitrage to hold both within as well as across financial markets. Deviations from these pricing conditions then necessarily translate into the failure of the law of one price.

2.2 Measures for international financial integration

International financial integrated markets do not allow for cross-border arbitrage opportunities. Using this definition of financial integration, we use the above pricing equations, (1) to (3), to measure the degree of financial integration. This framework is used to test for the equality of pricing kernels across markets. More specifically, we extend the home market by the set of exchange rate adjusted payoffs from the foreign market and test for equality of pricing characteristics of equivalent payoffs. Denote the domestic payoff space by $\mathcal{X}$, with $\sum_{i=1}^{N} c_i X_{i,t+1} \in \mathcal{X}$ for $c_i \in \mathbb{R}$ and construct the home currency denominated foreign payoff space by $\mathcal{X}^f$ with $\sum_{i=1}^{N^*} c_i \left(X_{i,t+1}^* \cdot S_{t+1} \right) \in \mathcal{X}^f,\ c_i \in \mathbb{R}$. Financial integration, i.e. the absence of cross-border arbitrage opportunities, implies that a single pricing kernel prices both the home and foreign sets of payoffs.

In order to obtain an operational measure for international financial integration we compute the minimal distance between the sets of pricing kernels $\mathcal{M}$ and $\mathcal{M}^f$ defined respectively on $\mathcal{X}$ and $\mathcal{X}^f$. Moreover, by normalizing the payoff space to payoffs with unit norm, we obtain a distance measure that can be compared across portfolios. Define the space of gross returns obtainable in the home market by $\mathcal{G}$ with $\sum_{i=1}^{N} c_i X_{i,t+1} (\sum_{i=1}^{N} c_i P_{i,t})^{-1} \in \mathcal{G}$ and the space of home currency denominated gross returns obtainable from foreign investments by $\mathcal{G}^f$ with $\sum_{i=1}^{N^*} c_i S_{t+1} X_{i,t+1}^* (\sum_{i=1}^{N^*} c_i S_t P_{i,t}^*)^{-1} \in \mathcal{G}^f$. Define the integration measure, $D\left(\mathcal{M}, \mathcal{M}^f\right)$, between the home and the foreign market as the minimal distance between the pricing kernels $m_{t+1} \in \mathcal{M}$ and $m_{t+1}^f \in \mathcal{M}^f$ defined on the spaces $\mathcal{G}$ and $\mathcal{G}^f$, respectively as:

$$D\left(\mathcal{M}, \mathcal{M}^f\right) = \min_{m \in \mathcal{M}, m^f \in \mathcal{M}^f} \left\| m_{t+1} - m_{t+1}^f \right\|, \tag{4}$$

where the norm $\|X\| = \sqrt{E\left[X^2\right]}$. The measure $D(\mathcal{M}, \mathcal{M}^f)$ has an interesting interpretation. More specifically, D measures the degree of mispricing on typical unit norm gross returns. According to proposition 2 of CK (1995) the distance measure can be interpreted as the pricing discrepancy between the observed home currency price of a foreign asset, $P_{i,t}^f = E_t\left[m_{t+1}^f \left(X_{i,\ t+1}^f\right)\right]$ for any $X_{i,t+1}^f \in \mathcal{G}^f$, and the price that would be given to this payoff if it were directly priced in the home market, $P_{i,t,m}^f = E_t\left[m_{t+1} \left(X_{i,\ t+1}^f\right)\right]$. Similarly, the same interpretation holds for any price in the home market, $P_{i,t} = E_t\left[m_{t+1} X_{i,\ t+1}\right]$ for any $X_{i,t+1} \in \mathcal{G}$, and the price that would be given it it were priced in the other market $P_{i,t,m^f} = E_t\left[m_{t+1}^f X_{i,\ t+1}\right]$. Formally:

$$\begin{aligned} D\left(\mathcal{M}, \mathcal{M}^f\right) &= \inf_{m \in \mathcal{M}} \sup_{X^f \in \mathcal{G}^f,\ \|X^f = 1\|} \left| P_{i,t,m}^f - P_{i,t}^f \right| \\ &= \inf_{m^f \in \mathcal{M}^f} \sup_{X \in \mathcal{G},\ \|X = 1\|} \left| P_{i,t,m^f} - P_{i,t} \right|. \end{aligned} \tag{5}$$

Since this interpretation holds for any unit norm payoff, distances can be compared across markets and country combinations. Given our set-up in terms of gross returns, implying unitary equilibrium price levels, we can interpret the distance $D(\mathcal{M}, \mathcal{M}^f)$ as an upper bound of the percentage pricing error for portfolios with unit norm gross returns, $ppe(X)$:

$$ppe(X) \leq D\left(\mathcal{M}, \mathcal{M}^f\right) \qquad for\ \ \|X\| = 1 \tag{6}$$

The obtained distance measure can be seen as a measure for cross-market failures of the law of one price and hence as a measure for imperfect financial integration. The higher the distance measure the higher will be the percentage pricing errors on portfolio's with identical (gross) return characteristics.

Note that the above analysis is done without imposing a positivity constraint on the pricing kernels. We opt for this approach as we are primarily interested in assessing cross-market arbitrage opportunities. If the law of one price does not hold, then, irrespective of whether the set of pricing kernels is restricted or not, arbitrage opportunities will exist across markets. In short, for our purpose the weak form integration measure (see CK) is sufficient to measure international cross-market integration.

3 Empirical results

In this section we present the results of implementing the integration measures. We find that arbitrage opportunities are quite substantial. Subsequently, we analyze possible market structure factors that may explain the existence of these arbitrage opportunities.

3.1 Data and implementation

To analyze whether submarkets of the European financial market are integrated or to what extent pricing errors exist between them, we estimate a pair-wise integration measure for a German (DEM) and a US (USD) investor investing in other financial markets being part of the European financial market: Italy (ITL), Spain (ESP), France (FRF), the Netherlands (NLG) and Belgium (BEF). It is important to note that even if these markets are pair-wise integrated, the complete European market might still be characterized by segmentation. We also compute an intra-Germany and intra-US integration measure by splitting the German and US market into two submarkets. These two measures can serve as a benchmark for the other integration measures. In total this gives fourteen pair-wise integration measures.

The data we use are the constituents of Datastream Global Market Indices for the seven markets.[2] We gathered monthly data for the period January 1995 until December 2002. The data are in local currency. End-of month exchange rates (DEM/euro per foreign currency and USD per foreign currency) are used to convert the payoffs to a common currency. All data are from Datastream.

Each integration measure between any two countries is estimated for 1000 random submarkets of these two countries. Each submarket is constructed by randomly selecting 25 equally weighted portfolios consisting of 10 randomly selected assets from the total number

[2] For Germany this gives 143 assets, for the US 765 assets, for Italy 88 assets, for Spain 75 assets, for the Netherlands 92 assets and for Belgium 53 assets.

of assets available in each market.[3] Each portfolio constructed this way is referred to as a base portfolio. As CK correctly note, using portfolios instead of individual assets reduces data measurement errors. For any two countries, this yields 1000 integration measures and allows us to draw more robust conclusions on the distance measures. In computing these integration measures, we account for the impact of the introduction of the euro. This is done by breaking up the time-series in two subsamples (with time-series length $T = 48$). The first sample is the pre-EMU period from January 1995 until December 1998. The second subperiod is the EMU period from January 1999 until December 2002. This gives two symmetrical subsamples of four years around the euro-introduction, and yields insights to whether pricing discrepancies have increased or decreased.

To compute the minimax bound of the distance measure on a given set of submarkets, we use the algorithm proposed by CK. This algorithm can be summarized as follows. Consider two sets of gross returns: those constructed by drawing randomly from the home market are collected in the $(N \times 1)$ vector $\mathbf{X}_{t+1}$, for $t = 1, ..., T-1$. Those constructed from the foreign stock market (after currency conversion) are collected in the $(N \times 1)$ vector $\mathbf{X}^f$ for $t = 1, ..., T$. Let $\boldsymbol{\iota}$ denote an $N \times 1$ vector of ones. The algorithm finds the minimax bound by iterating over the following steps, for $t = 1, ..., T-1$:

Step 1: Let $j = 1, ..., J$ denote the iteration number. For $j = 1$, initialize the stochastic discount factors on the random payoff sample as:

$$m_{t+1}^{(j)} = \mathbf{X}_{t+1}(E\left[\mathbf{X}_{t+1}\mathbf{X}_{t+1}'\right])^{-1}\boldsymbol{\iota},\ t = 1, ..., T-1 \tag{7}$$

Step 2: Given $m_{t+1}^{(j)}$, compute the discount factor $m_{t+1}^{f(j)} \in \mathcal{M}^f$ that yields the minimum distance with $m_{t+1}^{(j)}$ and the associated squared norm $D\left(\mathcal{M}, \mathcal{M}^f\right)^{(j)}$:

$$m_{t+1}^{f(j)} = m_{t+1}^{(j)} - \boldsymbol{\lambda}^{f(j)\prime}\mathbf{X}_{t+1}^f \tag{8}$$

$$\boldsymbol{\lambda}^{f(j)} = \left(E\left[\mathbf{X}_{t+1}^f \mathbf{X}_{t+1}^f{}'\right]\right)^{-1}\left(E\left[\mathbf{X}_{t+1}^f m_{t+1}^{(j)} - \boldsymbol{\iota}\right]\right) \tag{9}$$

$$D(\mathcal{M}, \mathcal{M}^f)^{(j)} = \left[\left(E\left[\mathbf{X}_{t+1}^f m_{t+1}^{(i)} - \boldsymbol{\iota}\right]\right)'\left(E\left[\mathbf{X}_{t+1}^f \mathbf{X}_{t+1}^f{}'\right]\right)^{-1}\left(E\left[\mathbf{X}_{t+1}^f m_{t+1}^{(i)} - \boldsymbol{\iota}\right]\right)\right]^{\frac{1}{2}} \tag{10}$$

Step 3: Given $m_{t+1}^{f(j)}$ compute analogously the adjusted pricing kernel $m_{t+1}^{(j+1)}$, $\boldsymbol{\lambda}^{(j+1)}$ and $D(\mathcal{M}, \mathcal{M}^f)^{(j+1)}$ according to (8), (9) and (10).

[3] As correctly noted by Ayuso and Blanco (2000), the cross-sectional dimension $N + N^*$ should be larger than the time-series dimension T. Otherwise, the system would be overidentified and the distance measure will always converge to zero. By constructing portfolios of 25 assets for the subsamples, this condition is guaranteed.

Step 4: Re-iterate the above mentioned Steps 2 and 3 until the distance measure converges to a stable point. End the search for the minimal distance if $\left|D(\mathcal{M}, \mathcal{M}^f)^{(j)} - D(\mathcal{M}, \mathcal{M}^f)^{(j-h)}\right| < tol$ for some user-defined values of h and tol. In the empirical application we use $h = 5$ and $tol = 10^{-6}$. We replace the expectations operator by the empirical mean operator: $E[X] = \frac{1}{T}\sum_{t=1}^{T} X_t$.

Note that CK show that the mappings are contraction mappings and hence that a solution to the minimal distance problem exists as long as the space is restricted to payoffs that are square integrable. By using gross returns, square integrability seems reasonable. In all of the simulations we find a contraction mapping that converges rather quickly to the lower distance bound.

3.2 Results

Table 1 reports the results for the integration measure between the sets of pricing kernels for the period 1995-1998. The distance measures are large. Comparing to the benchmark distance measures (DEM-DEM or USD-USD), all of the bilateral measures are consistently higher. This indicates cross-border mispricing. Looking at the DEM viewpoint distance measures, it can be seen that the EU combinations yield, in general, lower distance measures compared to the USD viewpoint distance measures. This indicates that EU pricing errors are lower compared to non-EU pricing errors for the period 1995-1998. The integration process in the EU, then, has lead to more efficient pricing across countries.

Table 1: **Integration Measure (1995-1998)**

	Mean	St. Dev.	Min.	Max.
$D(\mathcal{M}, \mathcal{M}^f)$	DEM Viewpoint			
ITL	0.3376	0.1748	0.0210	1.1879
ESP	0.3311	0.1735	0.0177	1.1743
FRF	0.3946	0.2075	0.0138	1.3432
DEM	0.2468	0.1294	0.0234	0.7731
NLG	0.3666	0.1989	0.0256	1.1726
BEF	0.5194	0.2690	0.0238	1.4505
USD	0.3697	0.1993	0.0333	1.2316
$D(\mathcal{M}, \mathcal{M}^f)$	USD Viewpoint			
ITL	0.3714	0.1855	0.0203	1.0328
ESP	0.3588	0.1900	0.0304	1.1822
FRF	0.3841	0.2075	0.0331	1.1889
DEM	0.3711	0.1925	0.0181	1.2108
NLG	0.4118	0.2158	0.0153	1.3742
BEF	0.4945	0.2641	0.0448	1.5783
USD	0.3168	0.1746	0.0245	0.9650

Whether this process continued after the introduction of the euro can be seen in Table 2. This table reports the results of the integration measure for the period 1999-2002. Looking at the DEM view point we see that monetary unification did not fully eliminate pricing discrepancies. The average values for mispricing in the top panel of table 2 are still significant We do find, however, that the pricing errors decreased, except for two market combinations, i.e. DEM-ITL and DEM-ESP. For these two market combinations we see a slight increase in the distance measures, indicating increased pricing errors. For all of the other markets, there is a decline in the pricing errors. So, while monetary unification did not eliminate the pricing errors we observe in most markets a decrease in the average mispricing. Note that the decrease in pricing errors can also be observed for the market combinations from the US point of view. Moreover, we tend to find a stronger decrease in the mispricing for the US viewpoint than from the DEM viewpoint. Apparently, comparing table 1 and 2 we find an increase in financial integration on a global scale, as exemplified in the decrease of the average pricing errors.

Table 2: **Integration Measure (1999-2002)**

	Mean	St. Dev.	Min.	Max.
$D(\mathcal{M}, \mathcal{M}^f)$		DEM Viewpoint		
ITL	0.3515	0.1826	0.0210	1.1862
ESP	0.3459	0.1826	0.0248	1.0189
FRF	0.2827	0.1474	0.0262	0.8164
DEM	0.2078	0.1138	0.0173	0.7815
NLG	0.3109	0.1568	0.0169	0.9341
BEF	0.3472	0.1776	0.0119	1.0145
USD	0.2935	0.1515	0.0198	0.9862
$D(\mathcal{M}, \mathcal{M}^f)$		USD Viewpoint		
ITL	0.3228	0.1725	0.0268	1.1432
ESP	0.3292	0.1794	0.0170	1.1820
FRF	0.2517	0.1279	0.0272	0.7272
DEM	0.3021	0.1585	0.0301	0.9110
NLG	0.2940	0.1529	0.0241	0.9608
BEF	0.3347	0.1751	0.0218	0.9570
USD	0.2295	0.1214	0.0125	0.7334

The level of mispricing resulting from the distance measures is significant, implying that large arbitrage opportunities are present. This result seems in sharp contrast to the academic belief that financial markets offer no arbitrage opportunities (Welch (2000)). It is important to note that the distance measures reported here constitute an upper bound on pricing errors. That is, the discount factors are constructed such that they have to price *any* linear combination of the base portfolios.[4] In this case, it is not unlikely that large mispricings can be detected. In reality, however, several payoff combinations are impossible to construct due to institutional constraints, short selling constraints and transactions costs

[4] Note that the reported distance measures, i.e. pricing errors, constitute an upper bound to any linear, L^2-integrable, combination of the base portfolio's. These linear combinations can among other things consist of extreme short selling positions are extreme risk positions in specific base portfolio's.

(bid-ask spreads, margins, commissions). In this sense, mispricings are often due to limits to arbitrage. These limits result from the risky and costly arbitraging process. The mispricing reported here should, therefore, not be confused with textbook arbitrage opportunities. Mispricing equals an arbitrage opportunity, only when a sure positive return, with positive probability, *can* be obtained at *zero cost*. In this respect, the evidence presented here might indeed constitute evidence of the existence of important institutional limits to arbitrage. Evidence on institutional limits to arbitrage in closed-end funds, dual listed companies, hedge funds and equity carve-outs is provided by Schleifer and Vishny (1997), Froot and Dabora (1999), de Jong et. al. (2003) and Lamont and Thaler (2003).

To put these upper bounds on pricing errors somewhat in perspective, we also computed cross-market pricing errors on simple and feasible portfolio's. More specifically, we use the unit norm, equally weighted portfolio's out of the foreign market base assets as the simple base portfolios. Using equation (6) we calculate the pricing discrepancy that arises if one would price an equivalent portfolio (with the same stochastic properties in the home market). The computed pricing errors then refer to pricing errors of specific and simple equally weighted portfolio's. If extreme positions are to explain the relatively high values for the upper bound on pricing errors, we would expect to find relatively small pricing errors for the simple portfolio's that we construct. Results for these pricing errors are reported in Table 3 and 4 for the period 1995-1998 and for the period 1999-2001, respectively. For the period 1995-1998 in Table 3, we see that observed pricing errors are much smaller than suggested by the distance measures. The pricing errors reported here are small, lower than 4%. Pricing in both markets is very similar, suggesting that, as far as simple portfolio's are concerned, there is efficient cross-border pricing. These results are in line with Pagano and Röell (1993). Table 4 reports the pricing errors for the EMU-period 1999-2001. We see that pricing errors decreased significantly compared to the pre-EMU period. The pricing errors did not only decrease on average, but also the maximum pricing errors decreased significantly. This suggests that markets have become more integrated over time. This is certainly true for the German viewpoint, suggesting that the introduction of the euro had a positive impact on the elimination of pricing errors.

3.3 Market Structure and Arbitrage

The integration analysis indicates that the degree of financial integration, as measured by the upper bound on pricing discrepancies varies both across the market combination analyzed and across time period. In general, we tend to find a decreasing trend in pricing errors indicating that, globally speaking, we have increased financial integration. However, there is the observation that there is quite some cross-sectional variation across market

Table 3: **Pricing Errors (1995-1998)**

	Mean	St. Dev.	Min.	Max.
$ppe(X)$		DEM Viewpoint		
ITL	0.0254	0.0254	1.1E-06	0.2290
ESP	0.0205	0.0197	5.4E-07	0.3131
FRF	0.0189	0.0186	1.5E-06	0.1657
DEM	0.0030	0.029	6.2E-08	0.0276
NLG	0.0134	0.0151	4.9E-07	0.1829
BEF	0.0197	0.0195	4.1E-07	0.1840
USD	0.0207	0.0222	1.2E-06	0.3384
$ppe(X)$		USD Viewpoint		
ITL	0.0273	0.0276	1.9E-06	0.1999
ESP	0.0259	0.0236	7.3E-07	0.1833
FRF	0.0244	0.0244	1.2E-06	0.2803
DEM	0.0217	0.0232	4.8E-07	0.2477
NLG	0.0215	0.0245	1.5E-06	0.3148
BEF	0.0279	0.0287	2.0E-06	0.3176
USD	0.0044	0.0042	9.4E-08	0.0459

Table 4: **Pricing Errors (1999-2002)**

	Mean	St. Dev.	Min.	Max.
$ppe(X)$		DEM Viewpoint		
ITL	0.0158	0.0166	3.0E-07	0.2142
ESP	0.0144	0.0133	3.1E-06	0.0883
FRF	0.0121	0.0121	5.4E-07	0.1316
DEM	0.0029	0.0030	5.6E-08	0.0406
NLG	0.0112	0.0105	3.9E-08	0.0966
BEF	0.0128	0.0144	1.4E-07	0.1737
USD	0.0174	0.0156	5.3E-07	0.1123
$ppe(X)$		USD Viewpoint		
ITL	0.0244	0.0233	9.1E-07	0.2453
ESP	0.0237	0.0246	1.9E-07	0.2158
FRF	0.0174	0.0169	1.5E-07	0.2066
DEM	0.0177	0.0171	1.7E-06	0.1672
NLG	0.0188	0.0183	2.0E-06	0.2049
BEF	0.0226	0.0214	2.7-07	0.2389
USD	0.0040	0.0039	2.4E-07	0.0455

combinations in the pricing discrepancies. In this section we study factors that may explain both the time variation and the cross-sectional variation in financial integration. We focus on micro-finance factors as a possible explanation for the observed limits to arbitrage. The theory of market microstructure is built on the idea that asset prices might depart from its rational expectations value due to a variety of frictions. (see Madhavan (2000)). These frictions can be real or informational (Stoll (2000)). The former are due to processing costs, inventory risk or monopoly power, while the latter can be caused by the free trading option which is offered by quotes as well as by the presence of asymmetric information. These trading frictions make it more difficult to trade assets, and hence can be expected to create a degree of mispricing. In the literature on market microstructure the bid-ask spread is a commonly used measure of friction. A wide bid-ask spread causes the prices at which assets are traded to deviate from their rational expectations' value. This idea will be elaborated in this section.

The methodology used here is in the same spirit as the Demsetz (1968) model who studies the determinants of the spread between the bid and the ask price. In line with this model, we model the spread between two stochastic discount factors (for which the minimal distance is reached) as a function of log market value, volatility, log market activity and an integration dummy. The rationale for these variables is primarily based on processing costs and inventory risk. Market value should yield a negative coefficient. The price impact of block trades have shown to be large in small market capitalizations (see Keim and Madhavan (1996)). When the market value is considerable, large trades have no significant impact on the market. When market value is small, large trades might have an impact on the market, creating distortions in the pricing process. Also, pricing of assets will be more efficient and less costly in a large market compared to a small market, since the probability of finding a counterparty is higher in the former. The coefficient of market volatility should be positive. Volatility, typically created by noise traders, induces departures from the fundamental values. (see De Long et al. (1990)). A higher volatility is accompanied by larger pricing departures, and thus, larger pricing errors. Market activity should have an inverse relation with pricing errors. The higher the market activity, the higher the liquidity. This factor thus accounts for a liquidity premium (see Brennan et al. (1998)). Finally, financial markets are becoming more and more global and transparent, lowering cross-border pricing errors. This process is captured by the inclusion of a time-trend which represents the increased integration over time.

We estimate the following panel:

$$\begin{aligned} |m_t - m_{t,i}| &= \alpha_0 + \alpha_1 \ln(MV_{t,i}) + \alpha_2 \sigma_{t,i} + \alpha_3 \ln(VOL_{t,i}) \\ &\quad + \alpha_5 IDUM_t + \varepsilon_{t,i} \end{aligned} \tag{11}$$

with m_t the stochastic discount factor of the German market and $m_{t,i}$ the stochastic discount factor of the country i, for $i = ITL$, ESP, FRF, DEM, NLG, BEF and USD and $t = 1995.1, ..., 2002.12$. The variables $MV_{t,i}$, $\sigma_{t,i}$, $VOL_{t,i}$ and $IDUM_t$ represent the market value, the market volatility, the market activity and the time-trend respectively. We estimate a panel such that the above model is estimated jointly for all countries i. A similar panel is estimated for the USD viewpoint, with $i = ITL$, ESP, FRF, DEM, NLG, BEF and USD.

The difference between the stochastic discount factors used as the dependent variable result from the integration measures. For each of the 1000 pair-wise integration measures we compute the absolute difference between the stochastic discount factors for which a minimum is reached. Subsequently, we average over these 1000 absolute differences to yield a single time-series of absolute differences between the stochastic discount factors for each combination. The data of the micro-factors are monthly data from the Datastream Global Market Indices for the seven countries. Market value is the share price multiplied by the number of shares in issue. Monthly volatilities are computed as the standard deviations based on daily price data. Finally, market activity is computed as the trading volume, i.e., the number of shares traded during one month. The data of these micro-factors are from Datastream. The summary statistics of the micro-factors are reported in Table 5. We see that there is substantial cross-variation in the micro-factors. The largest absolute cross-variation can be found for the market activity indicator. The log of trading volume shows that Belgium is the least active market, while the Us is the most active market. A similar difference can be observed for the log of market value, with the smallest market capitalization for Belgium and the largest market capitalization for the Us. Finally, Belgium is also the least volatile market and Italy the most volatile market.

The results of the two panel estimations (11) are reported in Table 6. All of the micro-factors are estimated significantly and the signs of the estimated coefficients are as expected. The effect of the market capitalization (MV) is negative. A larger market corresponds with lower pricing errors. Also, an increase in market trading volume (VOL) induces lower pricing errors. Furthermore, volatility (σ) has a positive estimate. A more volatile market is characterized by more pricing errors. Finally, the integration dummy has a negative estimate on the pricing errors. Pricing errors declined over time. This represents the increased global financial integration. The R^2 of the USD panel is rather large. The micro factors explain

Table 5: **Summary Statistics Micro-factors**

	Mean	St. dev.	Min	Max
$ln(MV)$		DEM Viewpoint		
ITL	27.2542	0.6674	25.9253	28.0981
ESP	27.8280	0.5295	25.7278	27.4871
FRF	27.9401	0.5844	26.9055	28.7054
DEM	27.9614	0.4559	27.0560	28.5798
NLG	27.5061	0.4332	26.5811	28.0530
BEF	26.1103	0.4379	25.2136	26.5990
USD	30.3963	0.5535	29.2648	31.1515
σ				
ITL	0.0137	0.0056	0.0067	0.0356
ESP	0.0120	0.0049	0.0051	0.0300
FRF	0.0121	0.0052	0.0049	0.0298
DEM	0.0115	0.0055	0.0034	0.0297
NLG	0.0111	0.0064	0.0038	0.0330
BEF	0.0086	0.0049	0.0028	0.0281
USD	0.0134	0.0050	0.0061	0.0284
$ln(VOL)$				
ITL	22.7019	0.5788	21.3774	23.6892
ESP	20.6783	0.7983	19.0572	21.9485
FRF	20.4452	0.7908	19.0120	22.0312
DEM	20.3287	1.3234	18.3776	22.4729
NLG	20.9702	0.6988	19.5085	22.2604
BEF	17.3909	0.8243	15.9458	18.8200
USD	23.7690	0.7186	22.4934	24.9501
$ln(MV)$		USD viewpoint		
ITL	26.6571	0.2710	25.6116	27.3894
ESP	26.2308	0.8640	25.4141	26.7473
FRF	27.3429	0.4401	26.5241	27.9411
DEM	27.3642	0.3266	26.7422	27.8648
NLG	26.9090	0.3003	26.2156	27.3066
BEF	25.5132	0.3096	24.8464	25.9686
USD	29.7992	0.4108	28.9210	30.3632
σ				
ITL	0.0129	0.0051	0.0057	0.0345
ESP	0.0118	0.0047	0.0044	0.0264
FRF	0.0115	0.0049	0.0044	0.0291
DEM	0.0115	0.0050	0.0040	0.0268
NLG	0.0109	0.0055	0.0039	0.0324
BEF	0.0096	0.0044	0.0036	0.0286
USD	0.0109	0.0049	0.0032	0.0256

Notes: Market capitalization (MV) and market volatility (σ) are viewpoint dependent. Market trading volume (VOL) is viewpoint independent.

almost 38% of the variance in the pricing errors. The explanatory power of the micro-factors in the DEM panel is much smaller: the micro-factors only explain 10% of the variance in the pricing errors. Finally, the F-statistic tests the hypothesis that all estimates are jointly zero. This test is strongly rejected for both panels. Micro-finance factors are, thus, able to explain a considerable part of the cross-border pricing errors. This holds especially for the USD panel. A detailed analysis of the regression results and the fits do show that most of the explanatory power of the independent variables stems from the cross-sectional dimension. That is, the factors in the regression framework (more in particular all independent variables but the time trend) do fit quite well the cross-sectional variation in the pricing discrepancies. The time series properties of the pricing discrepancies are only fit by the time trend. Even though this trend is significant it does not explain a large proportion of the time variation in the pricing discrepancies.

Table 6: **Pricing Errors Explained**

Parameter	Estimate	St. error	p-value
	DEM Viewpoint		
α_0	0.5766	0.0603	0.0000
$\ln(MV_{t,i})$	-0.0075	0.0031	0.0150
$\sigma_{t,i}$	2.5556	0.5552	0.0000
$\ln(VOL_{t,i})$	-0.0057	0.0021	0.0050
$IDUM$	-0.0004	0.0001	0.0010
$R^2 = 10.1\%$	$F = 18.2$		
	USD Viewpoint		
α_0	0.7470	0.0460	0.0000
$\ln(MV_{t,i})$	-0.0118	0.0024	0.0000
$\sigma_{t,i}$	3.7588	0.4739	0.0000
$\ln(VOL_{t,i})$	-0.0073	0.0015	0.0000
$IDUM$	-0.0011	0.0001	0.0000
$R^2 = 37.8\%$	$F = 100.8$		

In order to put the different effects more in perspective, we compute the average contribution of the different micro-factors in the fit of the stochastic discount factor differences. That is, we compute the contribution of the different micro-factors for the average values of the independent variables reported in Table 5. Table 7 reports these results. From the table it is clear that market capitalization is the most important factor in the determination of the pricing errors. The larger the market capitalization, the smaller the pricing errors. This effect is most clear for the USD viewpoint, where we see the larger cross-sectional variation in the effect of the market value. Also trading volume is an important factor: the larger the trading volume on a certain market, the lower the pricing errors will be. Market volatility and the time-trend are less important factors.

Next to decomposing the average absolute pricing errors as done in Table 7, one can also gauge the importance of each of the independent variables from a time-series perspective.

Multiplying the estimated (semi-) elasticities by the average size of the shocks to the independent variables (i.e. the standard deviations reported in Table 5) yields the average time variation in the absolute pricing errors. Typically, we find in this dimension that volatility dominates. For instance, computing absolute changes in the pricing errors (DEM viewpoint) with respect to typical shocks yields 0.0038, 0.0128 and 0.0046 for market capitalization, volatility and market trading volume, respectively.[5] So while the cross-section is dominated by differentials in market capitalization and trading volume, time variability of the bound is more responsive to volatility.

Table 7: **Contribution of the Micro-factors in the Fit of the Model**

	model fit	α_0	$\alpha_1 \ln(MV)$	$\alpha_2\sigma$	$\alpha_3 \ln(VOL)$	$IDUM$
			DEM viewpoint			
ITL	0.2590	0.5766	-0.2044	0.0350	-0.1294	-0.0188
ESP	0.2619	0.5766	-0.2087	0.0307	-0.1179	-0.0188
FRF	0.2626	0.5766	-0.2096	0.0309	-0.1165	-0.0188
DEM	0.2616	0.5766	-0.2097	0.0294	-0.1159	-0.0188
NLG	0.2604	0.5766	-0.2063	0.0284	-0.1195	-0.0188
BEF	0.2849	0.5766	-0.1958	0.0220	-0.0991	-0.0188
USD	0.2285	0.5766	-0.2280	0.0342	-0.1355	-0.0188
			USD viewpoint			
ITL	0.2998	0.7470	-0.3146	0.0485	-0.1294	-0.0517
ESP	0.3123	0.7470	-0.3095	0.0444	-0.1179	-0.0517
FRF	0.2994	0.7470	-0.3226	0.0432	-0.1165	-0.0517
DEM	0.2997	0.7470	-0.3229	0.0432	-0.1159	-0.0517
NLG	0.2993	0.7470	-0.3175	0.0410	-0.1195	-0.0517
BEF	0.3312	0.7470	-0.3011	0.0361	-0.0991	-0.0517
USD	0.2492	0.7470	-0.3516	0.0410	-0.1355	-0.0517

4 Conclusion

In this paper we have analyzed the degree of international financial integration across some of the major financial markets in the world. We used the methodology of Chen and Knez (1995) to measure financial integration by the law of one price. Subsequently, we related the recovered arbitrage pricing errors to standard micro-structure factors. From a methodological point of view our paper adds to the literature by extending the set of assets on which relative pricing relations can be tested. In principle we can extend the set of assets to all traded assets. This extension of the cross-sectional sample size is important as it allows us to apply standard econometric tools to study the interaction between the micro-structure characteristics of financial markets and the degree of mispricing.

The main conclusions to draw from this analysis are twofold. First, unlike the literature on cross-listings, we do find relative pricing errors, i.e. arbitrage opportunities, to be quite

[5] Typical shocks are chosen at 0.5, 0.005 and 0.8 for market capitalization, volatility and trading volume, respectively.

substantial, even for the most developed financial markets. The main reason for this finding is that, using the CK metric, one assesses all types of possible arbitrage portfolio's and not only the most apparent ones, such as the cross-listed assets. Even though there is convincing evidence that cross-listed assets are priced according to the law of one price, our results suggest that there exist (equivalent) portfolio's across markets for which substantial mispricing would be observed. These portfolio's may, however, be very complex, imply extreme short positions and be in practical terms infeasible. The second finding of this paper is that the cross-market mispricings are to some extent explained by financial market characteristics. More specifically, we find that standard micro-structure characteristics of financial markets do explain a substantial part of the observed arbitrage opportunities. More specifically, we find the market capitalization, market volatility and market activity to be important determinants of the observed mispricings. These factors appear both statistically and economically important and square well with the explanation set out in Demsetz (1968).

References

[1] Backus, D.K., S. Foresi and C.I. Telmer (2001). Affine Term Structure Models and the Forward Premium Anomaly. *Journal of Finance* 56 (1): 279-304.

[2] Bodurtha, J., D.S. Kim and C. Lee (1995). Closed-end Country Funds and the US Market Sentiment. Review of Financial Studies 8 (3): 879-918.

[3] Brandt, M.W., J.H. Cochrane and P. Santa Clara (2001). International Risk Sharing is Better Than You Think. NBER Working Paper 8404. National Bureau of Economic Research, Cambridge.

[4] Brennan, M.J., T. Chordia and A. Subrahmanyam (1998). Alternative Factor Specifications, Security Characteristics, and the Cross-section of Expected Stock Returns. *Journal of Financial Economics* 49 (3): 345-373.

[5] Chen, Z. and P.J. Knez (1995). Measurement of Market Integration and Arbitrage. *The Review of Financial Studies* 8 (2): 287-325.

[6] de Jong, A., L. Rosenthal and M.A. van Dijk (2003). The Limits of Arbitrage: Evidence from Dual-Listed Companies. mimeo.

[7] De Long, J.B., A. Schleifer, L.H. Summers and R.J. Waldmann (1990). Noise Trader Risk in Financial Markets. *Journal of Political Economy* 98 (4): 703-738.

[8] Demsetz H. (1968). The Cost of Transacting. *Quarterly Journal of Economcs* 82 (1): 33-53.

[9] Froot, K.A. and E. Dabora (1999). How Are Stock Prices Affected by the Location of Trade? *Journal of Financial Economics* 53 (2): 189-216.

[10] Hansen, L.P. and R. Jagannathan (1997). Assessing Specification Errors in Stochastic Discount Factor Models. *Journal of Finance* 52 (2): 557-590.

[11] Hardouvelis, G., R. La Porta and T. Wizman (1994). What Moves the Discount on Country Equity Funds?, in The Internationalization of Equity Markets, J.A. Frenkel (ed.), Chicago: University of Chicago Press.

[12] Jorion, P. and E. Schwartz (1986). Integration vs. Segmentation in the Canadian Stock Market. *Journal of Finance* 41 (3): 603-616.

[13] Lamont, O.A. and R.H. Thaler (2003). Can the Market Add and Substract? Mispricing in Tech Stock Carve-outs. *Journal of Political Economy* 111 (2): 227-269.

[14] Madhaven, A. (2000). Market Microstructre: A Survey. *Journal of Financial Markets* 3(3): 205-258.

[15] Pagano, M. and A. Röell (1993). Shifting Gears: An Economic Evaluation of the Reform of the Paris Bourse, in Financial Markets Liberalization and the Role of the Banks, Conti, V. and R. Hamauiu (eds.), Camebridge: Camebridge University Press.

[16] Pagano, M. (1997). The Changing Microstructure of European Equity Markets. CSEF Working paper 4, Center for Studies in Economics and Finance, Salerno.

[17] Schleifer, A. and R.W. Vishny (1997). The Limits of Arbitrage. *Journal of Finance* 52 (1): 35-55.

[18] Stoll, H.R. (2000). Friction. *Journal of Finance* 55 (4): 1479-1514.

[19] Welch, I. (2000). Views of the Financial Economists on the Equity Premium and on Professional Controversies. Journal of Business 73 (4): 501-537.